ExxonMobil Environmental Services Company
2800 Decker Drive
Baytown, Texas 77520

Via Electronic Mail

September 13, 2017

ExxonMobil

Mr. Sean Sheldrake, Remedial Project Manager
Portland Harbor Superfund Site
USEPA REGION 10 Seattle WA 98101

Re: Portland Harbor Fish Tracking Pilot Study, June 2017

Dear Sean:

Attached please find a summary of the fish tracking pilot study performed in the Lower Willamette River in June 2017. All work was successfully executed in accordance with the May 31, 2017 work plan that we provided to you. The experimental design allowed side-by-side comparison of two acoustic telemetry systems at two locations representing different acoustic environments: Willamette Cove and RM11E. The results of the pilot study support the technical feasibility of a full-scale acoustic study in the Portland Harbor Study Area.

As you may recall, a camera pilot study was also performed. The results are summarized in an attached memorandum, and support the application of field cameras for a full-scale camera survey in the Study Area.

Please let me know if you have any questions on the pilot study results.

Sincerely,

Deborah A. Edwards

Deborah A. Edwards, Ph.D.
Global Sediment Technical Lead

cc: Karl Gustavson, USEPA OSRTI
Todd Bridges, USACE, ERDC
Christa Woodley, USACE, ERDC
Kevin Parrett, ODEQ
Elizabeth Weaver, Norton Rose Fulbright US LLP

Attachments:
A – Summary of Portland Harbor Fish Tracking Pilot Study Field Activities
B – US Army ERDC Review of Vendor Reports
C – Summary of Portland Harbor Camera Pilot Study
D – June 13-19, 2017 Camera Pilot Study Photographs (USB via mail)

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Memorandum

To	Deborah Edwards/ExxonMobil	Page	1
CC	Dave Roberson/de maximis, inc., Christa Woodley/USACE ERDC, Roy Leidy/AECOM		
Subject	Summary of Fish Tracking Pilot Study – Lower Willamette River		
From	Betsy Ruffle and Ryan McCarthy		
Date	September 12, 2017		

This memorandum summarizes the fish tracking pilot study performed from June 12 to June 19, 2017 in the Lower Willamette River in Portland, Oregon. A summary of the design and results is provided, and recommendations for vendor selection are provided. The scope of work for the pilot study was developed in collaboration with Karl Gustavson, U.S. EPA Office of Superfund Remediation and Technology Innovation (OSRTI), who has extensive experience designing and implementing fish tracking studies. The pilot study was discussed with Sean Sheldrake of U.S. EPA Region 10 and Karl Gustavson at a meeting in February 2017, where the pilot study design and candidate locations for equipment installation were discussed. Dr. Christa Woodley, Senior Fisheries Scientist with the U.S. Army Corps of Engineers, Engineer Research and Development Center (ERDC), also assisted with study design, participated in execution of the field work, and provided expert review and analysis of vendor reports and results.

Pilot Study Design

An experimental design was developed to allow side-by-side comparison of two different acoustic telemetry equipment systems in the Lower Willamette River environment. The pilot study design was documented in a scope of work dated April 7, 2017, which was provided to two vendors (HTI-Vemco USA and Lotek Wireless Inc.), so that each could develop a proposal for implementation. Both vendors had participated in one-day pre-pilot equipment testing in February and March 2017, but due to different environmental conditions, direct comparison of results was not possible.

The experimental design involved deployment of a receiver array at two sites within the Lower Willamette River where resident fish (specifically, smallmouth bass) have previously been caught. Each site has unique acoustic properties based on bathymetry, bottom sediment composition, anthropogenic alteration, and noise, with Willamette Cove as the more quiescent location and RM11.5E the more active location. Each array consisted of five mounts deployed in a pattern designed to optimize detection and two-dimensional (2D) positioning of acoustic transmissions. The detection pattern was a quadrilateral with a central autonomous node (4 triangles of reception for 2D positioning) (Figures 1 and 2). The distances of the quadrilateral nodes were within the detection specifications of each vendor’s equipment (≤ 150 m). Each mount was outfitted with a single HTI-Vemco USA and Lotek Wireless Inc. autonomous receiver. Vendors also provided three transmitters to deploy on three stationary transmitting positions (stationary stations were placed in optimal, less optimal, and sub-optimal locations relative to the quadrilateral array), as well as two transmitters for mobile drags (where the tags were towed behind a vessels) to determine the maximum tag transmission distance and positioning from the receiver quadrilateral.

The vendors were allowed to propose the most appropriate gear for the pilot study, considering long-term study needs, and to pre-test and time-sync their equipment before deployment. The pilot study design resulted in an approach that ensured consistent and comparable spatial and temporal testing of vendor systems, while allowing each vendor suitable variance for the specific needs of their equipment. The April 7 scope of work included the following study questions which the vendors were asked to address:

1. What is the range of tag transmission and reception?
2. What is the efficiency of reception (i.e., number of transmissions sent from tags vs. number of transmissions received by receivers at specific distances) and the efficiency in positioning (i.e., number of transmissions vs. number of estimated fish positions)?
3. Are the technology platforms susceptible to code collisions?
4. What is the accuracy and precision of the positioning of tags?
5. If high-resolution 2-D positioning is not possible, what designs would permit lower resolution tracking at the site, for example, using “gates” or receiver transects to provide presence/absence information to isolate the presence of fish within segments of the river and river side?
6. What receiver installation/mounting techniques will be effective?
7. What are potential challenges associated with implementing a full-scale study?
8. What level of effort is required to maintain and obtain data from a deployed array?
9. What is your recommended equipment and a proposed receiver array for conducting the year-long full-scale survey for capturing SMB movement on a fine-scale basis and/or on a presence/absence basis?

The pilot study was performed in accordance with the May 30, 2017 work plan (AECOM 2017a), which was provided to U.S. EPA Region 10, and the Site-Specific Health and Safety Plan (HASP) (AECOM 2017b). Equipment was deployed and removed in full compliance with the safe work practices specified in the HASP (AECOM 2017b). Both vendors participated in the deployment and retrieval which also included AECOM staff, Christa Woodley (ERDC), and two research vessels (one with on-board davit) with captain and one crew supplied by Ballard Marine. A summary of the field activities is provided in a separate memorandum dated August 27, 2017 prepared by Ryan McCarthy, who served as the Field Team Lead (Attachment A).

Pilot Study Results

The results of the pilot study are presented in the reports prepared by each vendor (HTI-Vemco dated August 18, 2017 and Lotek dated August 29, 2017). Key findings are summarized in this memorandum. Detailed analyses of each vendor’s results relative to the study questions were performed by Christa Woodley with ERDC (August 25, 2017) and Roy Leidy, Senior Aquatic Biologist with AECOM (August 14, 2017). The ERDC review is provided in Attachment B. A summary of the camera pilot study also conducted is provided in Attachment C.

Both vendors’ systems collected acoustic data in the two pilot study areas using receiver hydrophones that were mounted approximately one meter above the bottom. For transmission, HTI-Vemco used a V-9 tag that transmits at 180 kHz and weighs 2.1 grams in water. Lotek used a dual-mode JSATS (acoustic) and SRX 800 (radio) (JCART) tag that transmits at 416.7 kHz (acoustic) and 166.42 MHz (radio). Both vendors’ acoustic tags were set to an agreed-upon transmission interval of 3 seconds (5 seconds for Lotek’s radio tag).

Due to a malfunction in their central node receiver at the Willamette Cove site, Lotek's ability to detect and position transmissions was severely limited at this location. Lotek identified a bad SD card as the likely cause of the issue (i.e., the receiver was working, however, the card was not recording data).

Tag detection efficiency is defined as the number of detections recorded between a defined start and end time, divided by the expected number of detections for the same time period, expressed as a ratio or as a percentage. A detection is defined as a correctly decoded tag signal ID that is recorded and stored by the receiver. For the stationary tags, the overall detection frequency (average for the three tags) and the range of detection efficiencies (for each individual receiver/tag combination) at the two sites are summarized in the following table:

Overall Detection Efficiency for Stationary Tags (Range in parentheses)		
Test Location	**HTI-Vemco**	**Lotek Wireless**
Willamette Cove	85% (77-100%)	24% (2-91%)
RM11.5 East	67% (32-97%)	54% (7%-90%)

At both sites, HTI-Vemco's overall detection efficiencies were higher than Lotek's, and had a narrower range.

In order for a position to be calculated, transmissions must be received simultaneously by at least three receivers. Position efficiency is defined as the number of calculated tag positions divided by the expected number of tag transmissions over the study period. The overall (average) and range of positioning efficiencies for the fixed tags at the two sites are summarized in the following table:

Overall Position Efficiency for Stationary Tags (Range in parentheses)		
Test Location	**HTI-Vemco**	**Lotek Wireless**
Willamette Cove	76% (53-92%)	0.6% (0.1-1.2%)
RM11.5 East	66% (51-77%)	51% (36-75%)

At both sites, HTI-Vemco's position efficiencies were higher than Lotek's.

Precision of position estimates for the fixed tags was calculated differently by each vendor and is summarized in the following table:

Stationary Tag ID	**HTI-Vemco**				**Lotek Wireless**		
	Number of positions with 3 or more receivers	**Error (m)**	**Number of positions with 4 or more receivers**	**Error (m)**	**Number of positions with DOP <1**	**Average position distance from tag (m)**	**Standard Deviation (m)**
Cove T1	123888	1.8	111829	1.13	1498	39.51	2.04
Cove T2	112650	4.72	99113	3.69	76	34.58	15.67
Cove T3	70667	9.84	7755	3.21	519	8.05	2.27
RM11E T1	105148	2.64	79946	2.28	46032	26.74	26.67
RM11E T2	96208	1.49	67716	1.12	89731	5.62	7.13
RM11E T3	69249	3.08	37458	1.31	38195	40.51	30.4

DOP – dilution of precision.

HTI-Vemco expressed tag position precision (position error) as the average horizontal distance between the Vemco position system (VPS)-calculated positions for a transmitter and the average of all the VPS-calculated positions for that transmitter. Lotek computed precision by calculating the average and standard deviation of the position estimate distances from the known tag location after filtering out dilution of precision (DOP) values greater than 1. Overall, the precision of position estimates was higher (lower error) for HTI-Vemco than for Lotek.

HTI-Vemco's overall results suggest that arrays with receiver spacing between 150-250 m (or more, depending on the site characteristics) would provide adequate detection capability for fine-scale positioning. For detection only, spacing of at least 200 m would provide very high levels of detectability for passing tagged fish. Lotek's results suggest that arrays of 50-100 m would provide adequate detection for fine-scale positioning, and 150 m spacing for detecting passing fish (gated system). Lotek included radio-telemetry capability in their pilot study using dual mode JCART tags and installation of land-based antennas at two locations at the RM11.5E site. However, due to sub-optimal conditions (blockage by structures and presence of barge), radio detections were limited. Lotek states that when properly sited, radio telemetry arrays can provide zonal coverage on the order of tens of meters, and is less costly than an acoustic system.

Summary and Recommendation

In summary, based on the results of the pilot study, the HTI-Vemco acoustic telemetry system performed better than the Lotek acoustic/radio telemetry system in the June 2017 Lower Willamette River pilot study. This conclusion is based on interpretation by AECOM and ERDC experts of the tests results from both the mobile (tag drag) and stationary monitoring performed at both study sites. The HTI-Vemco system appears to outperform the Lotek system when measured by detection distance, detection efficiency, tag positioning, and reliability (i.e., there were no equipment failures). The overall quality and completeness of the HTI-Vemco report was also better than Lotek's, including responses to the key study questions posed in the scope of work.

It appears that the lower frequency system employed by HTI-Vemco (180 kHz vs 416 kHz of Lotek tag) provided an advantage in the noisy Willamette River, which was noted by Lotek in their report. If an acoustic only system was selected, Lotek recommended using their 76 kHz MAP tag; however, this tag was not tested in the pilot study. Both vendors indicate that code collision is not expected to be a problem in a full-scale study, and the probability of code collisions is very low.

The ability to remotely check on the receiver status is an advantage of the HTI-Vemco system (at additional cost), reducing the number of times the receiver needs to be hauled to the surface to ensure it is working properly and redeployed with new GPS coordinates. HTI-Vemco's transponding system allows for remote monitoring of tilt, temperature, battery level, available storage space, and noise levels (note that receivers will still need to be retrieved for data downloading and maintenance). The receiver mount used in the pilot study was effective in terms of performance, security, and safe deployment/retrieval. A bathymetric map will facilitate selection of locations that provide optimal receiver positioning performance.

The results of the pilot study support the technical feasibility of a full-scale acoustic study in the Portland Harbor study area of the Lower Willamette River. Receiver arrays with similar spacing to the pilot study or slightly larger are expected to provide fine-scale positioning on the one to two meter scale. A design that combines receiver arrays in areas of specific interest with a series of receiver transects or "gates" that define the general zones of tagged fish is expected to provide reliable 2D positional data for estimating the home range of smallmouth bass in the study area.

References

AECOM. 2017a. Lower Willamette River – Acoustic Fish Tracking Pilot Study Work Plan, Portland Harbor Superfund Site, Portland, Oregon. Prepared for ExxonMobil Environmental Services, Houston, TX. Project No. 60531341. May 31, 2017.

AECOM. 2017b. Site-Specific Health and Safety Plan. Portland Harbor Superfund Site, Lower Willamette River, Portland, Oregon. Prepared for ExxonMobil Global Services Company, Houston, TX. Project No. 60531341. June 9, 2017.

Notes:

Figure 1
Vessel Routes and Actual Hydrophone and Camera Locations at RM11.5E Study Area
Lower Willamette River Fish Tracking Pilot Study
Portland Harbor Superfund Site

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Notes:

Figure 2
Actual Hydrophone and Camera Locations at Willamette Cove Study Area
Lower Willamette River Fish Tracking Pilot Study
Portland Harbor Superfund Site

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ATTACHMENT A

SUMMARY OF FISH TRACKING PILOT STUDY FIELD ACTIVITIES

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Memorandum

To	Deborah Edwards/ExxonMobil	Page	1
CC	Betsy Ruffle, Joe Luty, and Chris Altman/AECOM; Dave Roberson/dmi		
Subject	Portland Harbor Superfund Site Fish Tracking Pilot Study – Summary of Field Activities		
From	Ryan McCarthy, Pilot Study Field Manager		
Date	August 27, 2017		

This memorandum provides a summary of the field activities for the fish tracking pilot study performed at the Portland Harbor Superfund Site. The pilot study took place from 12 June to 19 June 2017 on the Lower Willamette River in Portland, Oregon. Implementation involved staff from several AECOM offices, Ballard Marine (vessel supplier), U.S. Army Corps of Engineers Engineer Research and Development Center (ERDC) staff, and two telemetry equipment vendors, Lotek Wireless Inc. and HTI-Vemco. A roster of the survey personnel and organizations that were involved in the pilot study field program is provided at the end of this memorandum. Select photos from the field program have been included as Appendix A.

Pilot Study Overview

The pilot study was performed in accordance with the 30 May 2017 work plan (AECOM 2017a) and the site-specific Health and Safety Plan (AECOM 2017b). The pilot study focused on two locations in the Lower Willamette River, Willamette Cove (WC, approximately located at river mile [RM] 6.8) and River Mile 11.5 East (RM11.5E) located near the Cargill Terminal. Willamette Cove was the more quiescent location and RM11.5E was the more active location. All on-river activities used the Cathedral Park Boat Ramp and parking area as the base of operations.

In order to meet the project objectives, acoustic receivers/hydrophones from both vendors (Lotek Wireless, Inc. and HTI-Vemco) were co-deployed on a rugged steel bottom mount that was specially fabricated for this study. The pilot design involved deployment of five mounts at pre-determined locations in both study areas. In addition to the receivers, transmitters were installed at varying distances to test the range and reception of the “pings” by the hydrophones that were deployed at the bottom of the river. A transmistter (tag) from each vendor was deployed on the same mooring at three locations representing optimal and sub-optimal distances from the hydrophone array. In addition to the use of fixed tags (which were left in place for the one week duration of the pilot study), a set of mobile tags were dragged by boat through the array at varying distances to provide another measure of acoustic range and reception with distance.

Kick-off Meeting

Prior to commencement of field activities, the program was initiated with a health and safety kickoff meeting at AECOM’s Portland office on 12 June 2017. The purpose of the meeting was to introduce the ExxonMobil Environmental Services (EMES) Loss Prevention System (LPS) to project team members, including AECOM staff, subcontractors, ERDC staff, and the telemetry vendors. The 4-hour meeting was led by Cris Altman, AECOM's U.S. Safety Health and Environment (SH&E) lead for EMES, and included EMES-specific LPS training, as well as site-specific project considerations, including boat and on-water safety, equipment deployment and recovery procedures. The meeting specifically addressed deployment of the bottom mounts, which each weighed over 100 lbs. and would be outfitted with precision instruments (acoustic receivers), requiring careful and well-orchestrated techniques for hoisting, moving, and deploying into the water using the vessel's winch.

Summary of Field Activities

The section provides a summary of the activities performed on the days involving field work. The total duration of the pilot study was eight days. Four days involved field work June 12, 13, 14 and 19; the telemetry equipment was left in place to collect data 15 June through 18 June. Prior to the start of each on-water field day, a float plan was prepared and submitted to a project coordinator in AECOM's Portland office. All health and safety forms and documents related to the pilot study project are stored at the AECOM-EMES Sharepoint site.

12 June 2017

During the afternoon of 12 June, the vendors prepared their equipment for deployment at the Cathedral Park boat ramp. This included finalizing hydrophone settings and installing them onto the mounts. During the afternoon, AECOM staff traveled by boat to the two pilot study locations to scout potential locations to install field cameras. Three locations were accessed by boat and cameras successfully installed (two at WC and one just south of the Cargill property at RM11.5E). The manager of the Cargill facility was contacted by phone and arrangements made to meet the next day to install the second camera on an upland location at the Cargill property.

13 June 2017

On the morning of 13 June, preparations for equipment deployment were completed, including installing the acoustic releases onto the mounts. Prior to the initiation of on-water work, a SH&E tailgate briefing/ orientation was held by Cris Altman to go over the proposed work activities for the day. Upon completion, two vessels from Ballard Marine were launched at the Cathedral Park Boat Ramp. After loading the vessels with the mounts to be deployed at Willamette Cove, they mobilized to the cove site.

An on deck davit was used to hand haul the sub-surface float and acoustic release into the air, so the bottom mount could be deployed overboard. The davit then lowered the equipment into the water until the sub-surface buoy was resting on the water's surface. A line was passed through a loop atop the buoy in order to manually lower the mount through the water column. A second tag line was attached to the bottom mount in order to control the descent of the equipment to the river bed.

Once on the bottom, a survey grade GPS (Juniper Geode and Sokkia handheld) recorded the as deployed position of each bottom mount. The buoy/ looped line was then released, and the bottom mount was left on the river bottom to record data. The tag line had two half-8 cinder blocks attached and then dropped overboard. This ground line served as a backup recovery option should the acoustic release fail during recovery.

Five mounts were successfully deployed at both Willamette Cove and the process was repeated in the afternoon at RM11.5E. During deployment at RM11.5E, careful coordination was required with the Cargill terminal manager to ensure that pilot study activities did not interfere with the busy shipping/ barge schedule. On Mooring #3 (Station 5) Christa Woodley from ERDC added a sound listening device to the bottom mount to record ambient background noise levels during the study (data to be provided separately).

Additionally, on 13 June, AECOM's field camera scientist Mandi McElroy met with Mr. Mark Jensen (Terminal Manager) at the Cargill facility and installed the second camera on a fence adjacent to the water with a view of the study area. The cameras deployed on 12 June were also checked to ensure they were operating properly.

<u>14 June 2017</u>

The Pilot Study team conducted a series of drift tests/ tag drags (transects) at each study area to gauge detection range, efficiency, and overall functionality of the deployed hydrophone array. Two tags from each vendor were zip tied to a fiberglass pole and mounted vertically alongside the research vessel. A GPS unit was able to record a trackline of each drift. Drift were conducted through the arrays and then at increasing distances from shore. Drift test results will be included in the respective vendor's summary reports.

After the drift tests, the Pilot Study team installed three fixed mobile tag moorings at both study area locations (WC and RM11.5E). These stationary tags were installed to test system performance (i.e., effectiveness) at a variety of distances. The fixed tag mooring consisted of a subsurface float, several concrete blocks, and a groundline for recovery.

Additionally, the HTI team was able to check on all of the deployed bottom mounts to ensure that they were deployed properly (i.e., sitting flush on bottom, not tipped over). It was determined that all receivers were active/ listening and that the degree of tilt on each receiver was within an acceptable range. Lotek also confirmed that their units were functional.

<u>19 June 2017</u>

The Pilot Study team reconvened at the Cathedral Park boat ramp on the morning of 19 June to recover the hydrophone moorings and fixed tags. Following a H&S tailgate meeting to discuss the day's activities, the team mobilized by boat to the Willamette Cove site. At each of the GPS positions where the mounts were deployed, an acoustic release "pinger" was used to activate the release and send the sub-surface buoy to the surface for recovery. The davit was used in addition to hand hauling the line to get the bottom mount back on board the research vessel. All five bottom mounts were recovered successfully at the WC study area. The fixed tags were dragged for using a grapple to attempt to snag the ground line. None of the fixed tags were recovered using this method. One sub-surface buoy was spotted visually, and the tags attached to that mooring was recovered.

At the RM11.5E study area, four out of five acoustic releases operated properly and those moorings were recovered. The fifth mooring was dragged for with a grapple and successfully found/ recovered. It was later determined that an internal part of the release was damaged and prevented the proper operation of the release. The fixed tags were dragged for using a grapple to attempt to snag the ground line. None of the fixed tags were recovered using this method at the RM 11.5E site. After demobilizing at Cathedral Park boat ramp, the ten receiver mounts were transported by trailer to AECOM Portland's equipment facility for storage.

Results and Discussion

The Pilot Study was successful from a field implementation perspective. The field activities, including boat trailering, equipment deployment, and all on-water work, were executed as planned and without incident. All ten of the bottom mounts were deployed and recovered with no damage or loss of the hydrophone receivers. All fixed tags were deployed successfully and the mobile tag drags were executed as planned. While five of the six fixed tags could not be recovered, this will not impact the ability of the vendors to analyze the acoustic data. All four field cameras were also successfully deployed and retrieved with no evidence of tampering or damage. The results of the field camera study are summarized in a separate memorandum dated July 31, 2017. Additionally, the program was completed on schedule with zero health and safety incidents.

Roster of Survey Personnel

AECOM
Ryan McCarthy, Manchester, NH
Mark Tauscher, Portland, OR
Mandi McElroy, Oakland, CA
Cris Altman, Conshohocken, PA

USACE, ERDC
Christa Woodley, Vicksburg, MS

HTI-Vemco
Sam Johnston, Seattle, WA
Jacob Owens, Seattle, WA
Dale Webber, Halifax, Nova Scotia, Canada
Eddie Kudera, Seattle, WA

Lotek
Matt Knoff, Seattle, WA
Mitch Sisak, Toronto, Ontario, Canada
Mark Morach, Moscow, ID

Ballard Marine
Alex Anderson
Jason Studinaz
Tony Beam
Joe Caldwell
Matt Shoemaker

AECOM

References

AECOM. 2017a. Lower Willamette River – Acoustic Fish Tracking Pilot Study Work Plan, Portland Harbor Superfund Site, Portland, Oregon. Prepared for ExxonMobil Environmental Services, Houston, TX. Project No. 60531341. May 31, 2017.

AECOM. 2017b. Site-Specific Health and Safety Plan. Portland Harbor Superfund Site, Lower Willamette River, Portland, Oregon. Prepared for ExxonMobil Global Services Company, Houston, TX. Project No. 60531341. June 9, 2017.

Appendix A

Field Work Photographs

Photographic Log

Project: Lower Willamette River Fish Tracking Pilot Study **Project No.:** 60531341

Client: EMES **Photo Date:** 6/12/2017 – 6/19/2017

Distribution: P:\Indl_Service\Project Files\ExxonMobil\Portland Harbor Sustainability\Pre-Design Studies\Fish Tracking\Pilot Study\Field Memo

Prepared by: Ryan McCarthy **Date:** 7/28/2017

Site Visit Photo Log

Photograph 1 ↑
Bottom Mounts outfit with HTI Hydrophone

Photograph 2 ↑
Bottom Mounts on Deck of Research Vessel

Photograph 3 ↑
Ballard Marine's R/V Argos

Photograph 4 ↑
Preparing to hoist bottom mount for deployment

Photograph 5 ↑
Preparing acoustic release for deployment

Photograph 6 ↑
Deploying bottom mount with acoustic receivers

Photograph 7 ↑
Lotek and HTI hydrophones being deployed

Photograph 8 ↑
Recording GPS position of deployed bottom mount

Photograph 9 ↑
Fish tags mounted to rod for drift tests.

Photograph 10 ↑
Bottom mount being recovered after week of deployment

Photograph 11 ↑
Typical barge/ bulkhead environment at RM11.5E

Photograph 12 ↑
Typical Barge at RM11.5E

ATTACHMENT B

USACE ERDC REVIEW OF VENDOR REPORTS

DEPARTMENT OF THE ARMY
ENGINEER RESEARCH AND DEVELOPMENT CENTER, CORPS OF ENGINEERS
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Memorandum- *Draft*

To: Ruffle, Betsy, AECOM, Chelmsford, MA
McCarthy, Ryan, AECOM, Manchester, NH

From: Woodley, Christa, PhD
Research Biologist

cc: Bridges, Todd

Date: 20170825

Subject: Review of Acoustic Telemetry Vendor Reports for the Pilot Study in the Lower Willamette River

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The following is a review of the reports submitted to AECOM by two vendors, HTI-Vemco USA and Lotek Wireless Inc. for a pilot study conducted in the Lower Willamette River from June 13 to June 19, 2017. The subject reports are HTI-Vemco's final report dated August 18, 2017 and Lotek Wireless, Inc.'s draft report dated July 27, 2017, supplemented by webinars by each vendor in August. Included in this memo are basic descriptions of the proposed equipment by each vendor, a brief overview of the technology differences, and discussion of each vendor's pilot study results organized by the eight key questions identified in AECOM's April 7, 2017 scope of work. Specific comments or recommendations made by ERDC are denoted in this memo with an asterisk.

Equipment used in pilot study:

HTI-Vemco USA

- Autonomous Receiver: Vemco HR2 Receiver. This receiver is powered by internal battery pack, monitors a narrow frequency band around 180 kHz, and uses a traditional pulse position modulation (ppm), which relies on the amplitude and with of the pulses and shifting the position (typically 8) of the pulse in time to represent a unique id. To detect a unique ID, the receiver determines the sequence of unique time differences between pulses and compares this sequence with the list of valid sequences and assigns the ID that matches, along with the date and time of arrival. The receivers can be communicated with remotely for status updates (i.e., tilt, battery level, number of detections, and number of detection ids). Internal storage was provided as PPM/HR: (170,000,000 detections).

- Acoustic transmitters: Vemco V-9. Transmitter frequency: 180 kHz at 143 dB (re 1µPA @ 1m). Transmitter size: 25 mm x 9 mm, 2.1 g in water.

Lotek Wireless Inc.

- Autonomous Receiver: WHS 4250 data logger. This receiver is powered by 1 to 4 lithium D-size batteries, monitors a narrow frequency band around 416.7 kHz, uses a decoding system specific to JSATS applications which is a Binary Phase Shift Key (BPSK), 31 bits composed of 8 bit CRC, 16 bit ID and 7 bit barker. BPSK conveys data by changing, or modulating, the phase of the reference signal to either 0 or 180 degrees. Each phase, in turn, corresponds to a binary digit (0 or 1). JSATS signals are 31-bits in length, 744 microseconds in duration, and are emitted at a programmed interval. Internal storage is 2 GB and can near communicate using Bluetooth technology (implicit-in air communication). The unit is slightly negative buoyant (opposed to neutrally buoyant that maintains the same depth in the water that it was deployed, negatively) when loaded with 4 D-size batteries.

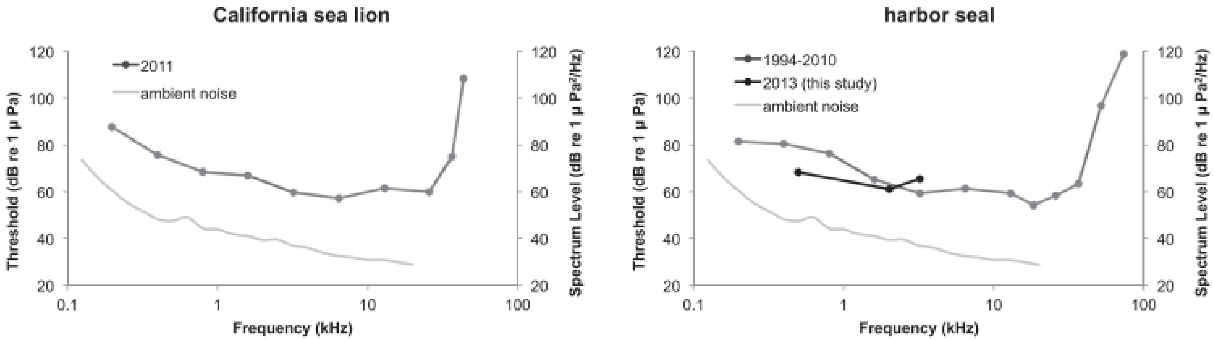
- Acoustic Transmitters: Dual Mode JCART which uses a JSATS (acoustic) and SRX 800 (radio) signaling system. Transmitting frequencies are dual band: 416.7 kHz (acoustic) at 153 dB (re 1µPA @ 1m) and 166.42 MHz (radio) at 3 sec and 5 sec burst rate (ping interval rate [PIR], or ping rate).

Based on the equipment used by each vendor, the following should be considered when reviewing the reports and for long-term deployment.

- Because of the transmitter frequency differences between vendor technologies, the equipment (transmitters, receivers, software) cannot be interchanged between vendors.

- Any acoustic or radio telemetry studies in the area within the range of the transmitting frequency will be detected on the either vendor's equipment deployed for the long-term study. Exclusion of erroneous transmitters will occur in the data processing stage. It is recommended that non-study tag information be returned to the vendor for their dissemination to other studies in the area. For example, if 50 fish bearing transmitters out-migrate through the study/river reach gates, those transmitter detections are returned to the vendor, who shall seek the transmitter's owner and provide them the collected data. A query of regional agencies and the request to the selected vendor should prove to be sufficient for understating the potential for non-study data collection. The JSATS frequency will likely capture more non-study data due to out-migrating salmonids projects focused Willamette River dams and reservoirs.

- The proposed gear by each vendor uses frequencies that are above the hearing of fish (> 10 kHz) and humans (> 20 kHz). The hearing range of marine mammals underwater detection thresholds are est. 50-180 kHz, depending on environmental noise and decibels (dB re 1 µPa). Diagrams below are from Cunningham 2016, doi: 10.1016/j.heares.2015.10.00. Based on resident marine mammal audio evoked potentials (see below), fish bearing the HTI transmitters may attract increased rate of predation, especially if sites are chosen closer to the confluence of the Lower Willamette River and the Columbia River. Recall California sea lions and Harbor seals are residents of the Columbia River and seen as far upriver as Bonneville Dam. Seal and sea lion use of the rivers are often seasonal and well documented. Marine mammal behavior, via telemetry data, usually provides unique patterns and easy to exclude from the dataset if the consume a fish bearing an acoustic transmitter. Therefore, one may consider increasing the sample size (number of deployed transmitters) to ensure the study criteria are maintained throughout the year at lower river sites.



- The difference between vendors in the transmitted and monitor frequency band will have direct implications on the wavelength, distance travelled and detection of the transmitted signal. For example, 1 kHz has a frequency wavelength of 1.6m, 180 kHz has frequency wavelength of 0.009m, and 416 kHz has a frequency wavelength of 0.004m, (all) travelling as 1600 m/s. The main cause of sound attenuation (sound loss, absorption) in fresh water is viscosity (water's inherent resistance to deformation) and therefore higher frequencies attenuate (absorb) more rapidly and thus tend not to travel as far as lower frequencies.

Radio and acoustic telemetry variance:
Because Lotek Wireless, Inc. utilized a dual mode transmitter that included both radio and acoustic capabilities, the following briefly overviews the benefits and limitations of the each technology.

- Radio receivers and transmitters do not operate well in high conductivity, or at water depths greater than > 20m. The radio receiving equipment is typically conspicuous and susceptible to vandalism. Power maintenance varies with system and environment. The receivers and data acquisition systems (DAQs) can be land based, solar-powered or battery-powered, thus reducing the potential for data loss to internal battery malfunction. In addition, radio receivers have a much reduced probability of lithium battery burns. Radio read ranges can, obviously, be detected in both water and air. In shallow water, radio receivers have the advantage over acoustic autonomous receivers due to size and deployment issues. In addition, radio telemetry allows a specific zone monitoring, and is not affected by aquatic vegetation or water turbulence.

  Radio transmitters use a quartz crystal to control frequency, and an antenna that may be coiled and encased within the tag package, or left out and trailing from the fish, to transmit information. Non-encased (often referred to as whip, trailing or external) antennas may foul and/or cause infection due to the constant rubbing on the fish tissue.

- Acoustic receivers and transmitters (often referred to as ultrasonic and sonic) involves the transmission of frequency sound signals (30-417 kHz). The receiver hydrophone converts the transmitted acoustic signal back to an electrical signal for detection and decoding in the receiver. Acoustic transmitters contain a transducer, circuit board, and battery, and is encapsulated in a thin epoxy resin (no external antenna). The acoustic transmitters work by allowing for the conversion of electrical energy to sound energy most often through the use of piezoceramics. Transmitters emit pulsed signals consisting of short bursts of sound waves. Depending on the signal coding methods, some methods (i.e., BPSK) allow for significantly more unique tags and more sophisticated tag positioning determinations. Regardless of acoustic signal coding, detection of the transmitted acoustic signal can be affected by ambient and anthropogenic underwater noise, the water physical-chemical properties, electrical noise from nearby equipment, underwater structures, etc. Location of the acoustic transmitter is determined from time-of-arrival detections on a single or an array of hydrophones, each detection having a date and time stamp. A limitation of acoustic telemetry is that acoustic signals do not pass the water-air interface and thus, detection systems only use underwater receivers. However, these receivers may be autonomous or land-based using a cabled system.

Regardless of the telemetry approach, produced signals from the transmitters and the ability to detect the transmitted signal can be reduced by natural (e.g., bathymetry, air bubbles, vegetation) and man-made (e.g., motors, vibrations, etc.) noise.

Pilot study design:

An experimental design was developed by Exxon-AECOM, with assistance from Engineer Research and Development Center (ERDC) experts and Karl Gustavson (now with the U.S. EPA Office of Superfund Technology and Innovation Program). The April 7, 2017 plan was provided to two vendors (HTI-Vemco USA and Lotek Wireless Inc.), so that each could develop proposals for implementing the pilot study design. The experimental design involved deployment of a receiver array at two sites within the Lower Willamette River where resident fish (specifically, smallmouth bass) have previously been caught. Each site has unique acoustic properties based on bathymetry, bottom sediment composition, anthropogenic alteration, and most importantly, anthropogenic noise. Each array consisted of 5 mounts deployed in an optimal detection pattern that should have maximized the ability of both vendors to achieve two-dimensional [2D], and possibly three-dimensional [3D] positioning. The detection pattern was a quadrilateral with a central autonomous node (4 triangles of reception for 2D positioning). Proposed distances of the quadrilateral were within the detection specifications of each vendor's equipment (≤ 150 m). Each mount (Exxon-AECOM supplied) was outfitted with a single HTI Vemco USA and Lotek Wireless Inc. autonomous receiver. Vendors were to provide three transmitters to deploy on three stationary transmitting positions (stationary stations were place in an optimal location, on the edge of the quadrilateral array and one slightly outside of the quadrilateral array) as well as two transmitters for mobile drags (where the tags were towed behind a vessels) to determine the maximum distance and 2D (and if possible 3D) detectability within, around and away from the receiver quadrilateral.

With the information provided by Exxon-AECOM, the vendors were allowed to propose the most appropriate gear for the pilot study, which should also reflect long-term study needs. Both vendors were allowed to initiate/power equipment, time-sync, and collect cursory data of their autonomous receivers before deployment. In addition, each vendor was allowed to adhere their equipment to the mount using their deployment methods of preference. The pilot study design resulted in a spatial approach specific to the client's (Exxon-AECOM) needs, though, allowing each vendor suitable variance for the specific needs of the equipment. Equipment was deployed and removed in full compliance with the safe work practices specified in the AECOM-ExxonMobil Site Specific HASP. Each vendor was allowed to participate in the deployment/retrieval that also included Exxon-AECOM assistance, US Army Corps of Engineers assistance, and two Exxon-AECOM supplied vessels (Ballard Marine).

Lastly, Exxon-AECOM provided the below questions to each vendor, allowing the vendors to use their data analyses coding, procedures, and software.

For the data collection and processing each vendor was asked to address the following questions:

1) What is the range of tag transmission and reception?
2) What is the efficiency of reception (i.e., number of transmissions sent from tags vs. number of transmissions received by receivers at specific distances) and the efficiency in positioning (i.e., number of transmissions vs. number of estimated fish positions)?
3) Are the technology platforms susceptible to code collisions?
4) What is the accuracy and precision of the positioning of tags?
5) If high-resolution 2-D positioning is not possible, what designs would permit lower resolution tracking at the site, for example, using “gates” or receiver transects to provide presence/absence information to isolate the presence of fish within segments of the river and river side?
6) What receiver installation/mounting techniques will be effective?
7) What are potential challenges associated with implementing a full-scale study?
8) What level of effort is required to maintain and obtain data from a deployed array?
9) Recommended equipment and a proposed receiver array for conducting the year-long full-scale survey for capturing SMB movement on a fine-scale basis and/or on a presence/absence basis.

Pilot study questions:

1) *What is the range of tag transmission and reception?*

Cove Site (Willamette Cove): The dimensions of the Cove site (Willamette Cove) acoustic array was slightly adjusted during deployment due to resident boaters in the Cove. The quadrilateral post-deployment was 106m x 139m x 88m x 237m. The site was chosen for its gradual bathymetry, fine-sediment dominance (> 60%), quiescent to low flow and quiet acoustic conditions.

Port Site (RM11): The dimensions of the Port site (RM11) acoustic array was slightly adjusted during deployment due to bathymetry and commercial barge/tow wash at time of deployment. The quadrilateral post-deployment was 96m x 98m x 104m x 109m. The site was chosen for the complex acoustics due to the commercial and recreational vessel use, seasonal rapid flow, bridge vibration & acoustics (vehicle and train), low fine-sediment (< 20%), and steep bathymetry.

<u>HTI-Vemco USA</u>: The Vemco HR2 180 kHz system detected transmitters during “the tag drag tests to 400 meters at the Cove, and 250 meters at River Mile 11 (Table 5 and Figures 13-22 of HTI-Vemco report). The VPS arrays were deployed at a receiver spacing of approx. 100 to 150 meters (average distances between receivers was 140 m for the Cove and 105 m for RM 11). These results suggest that arrays with receiver spacing between 150-250 meters (or more, depending on the site characteristics) would provide adequate detection capability for good positioning. For detection only, spacing of at least 200 m would provide very high levels of detectability for passing tagged fish. (Report page 23)

In reference to the Cove site: “Overall, the average tag detection efficiencies for each tag were very high and the average ranged from 83.40% to 87.21%. The individual receiver tag detection efficiencies ranged from a low of 76.32% to a high of 99.69%. (Report page 9)

In reference to the Port site: “The tag efficiency at the RM11 site for the three stationary tags is presented in Table 4. The RM11 site was acoustically noisier than the Cove site and consequently the detection efficiencies were lower. The individual receiver tag detection efficiencies ranged from a low of 32.29% to a high of 97.16%. Overall, the average tag detection efficiencies for each tag ranged from 59.79% to 71.27%." (Report page 9)

Lotek Wireless Inc.: Observed equipment failures (central node failure in the Cove array), biased their ability to report a reception-transmission range for the Cove site. Lotek stated throughout the report several times that the expected distance of detection is typically between 75-150m for the JCART transmitter. With the Cove site central node failure, 3 of the 5 receivers were more than 150 m from each other, and therefore Lotek reports a very low detection capability. For the Port site, the Lotek system had greatly improved detection efficiencies indicating that the transmitter/receiver range of < 109m (based on maximum distance & efficiency data provided within the report; Figure 15 and Figure 17) is appropriate.

*Based on the transmitted frequencies used by each vendor, one can reasonably conclude that the lower frequency (greater wavelength) would be subject to less attenuation, and therefore should have greater detection and maximum distance detection. Consideration for the long-term study should take into account array design and need for maximum detection distances. HTI-Vemco recommendation for 200m, based on their data, is appropriate for their equipment.

2) *What is the efficiency of reception (i.e., number of transmissions sent from tags vs. number of transmissions received by receivers at specific distances) and the efficiency in positioning (i.e., number of transmissions vs. number of estimated fish positions)?*

HTI-Vemco USA: "Detection efficiency was generally very high, with some lower detection efficiencies at the RM 11 site, primarily due to increased noise levels. Combining data from all receivers, the detection efficiency for the three stationary tags combined at the Cove site was 85.13 percent (1,721,194 detections of 2,021,795 expected), and 66.68 percent (1,374,771 detections of 2,061,778 expected) for the River Mile 11 site. Tag positioning efficiency results for stationary tags are summarized in Table 6, with Figures 25 and 26 indicating positioning results for the tag drag tags. Tag positioning efficiency was generally high, especially for stationary tags that were within the array boundaries. Overall positioning efficiency for stationary tags at the Cove site was 76.38 percent (307,205 positions of 402,200 expected tag transmissions), and 65.98 percent for the Port site (270,605 positions of 410,147 expected tag transmissions). The lowest positioning efficiency for the 'all Positions' category was at the RM11, stationary Tag 3 at 50.51 percent (located furthest outside of the Port array). The report notes, "A positioning efficiency of 50 percent is still quite useable, and would produce tracks of fish movement with positions every 6 seconds on average, for tags transmitting every 3 seconds." (Report page 23).

HTI-Vemco USA did not address in Figure 8 the detections and detection efficiencies that occurred at distances great than 250m. If the tag drag detections noted in Figures 13-22 are present, one can conclude that the detection efficiency was low at distances greater than 250 m and not within the acceptance criteria of the vendor. Those criteria were not made available to Exxon-AECOM, but we know from past experience that the criteria are generally vague and often based on professional judgment for the current monitoring situation.

HTI-Vemco USA captures the transmitter position estimates well in Table 8. In this table, they present both the 3 receiver and 4 receiver position estimate errors. Position errors ranged from 1.8 to 9.8 m at the Cove site for 3 receivers, and from 1.13 to 3.7m for 4 receivers. For the Port site, position errors ranged from 1.5 to 3.1m for 3 receivers and 1.1 to 2.3m for the 4 receivers. Based on this, one can conclude that the array design at the Cove site was a challenge for the vendor gear, potentially due to moving one of the receivers (Cove-1 in Figure 4 of report) further from the array than originally planned to accommodate a resident boater. At any time, 4 receivers can be used to position a fish, one should expect a reduction in the positions estimate error, which is why the 4 receiver system produces smaller error estimates compared to the 3 receiver system. 4 receiver systems allow for 3D detection as well.

Lotek Wireless Inc.: The report only addressed the number of transmissions sent, received transmissions at specific distances, efficiency in positioning for the transmitter drag test. Figures 15 and 17 of the Lotek report provide detailed tables that captures their detection efficiencies by the node-node relationship. The detection efficiencies for the Cove site transmitter drag data was very low (Section 3.2a) "never more than 40% in the Cove drift tests, which suggests that the probability of position estimates being generated is extremely low." Lotek provides sensible reasons for the poor detection efficiency that is without the central autonomous node, the node placement range was greater than that of the transmission range. Two position solutions were developed (Figure 16) by the UMAP software, which is very low; the positions estimates are not provided with an error rate.

Port array drift tests detection efficiencies greatly increased compared to the Cove site (Figure 17), ranging from 0 to 100 percent. The Port detection efficiencies for the receivers were improved over that seen in the Cove with much higher numbers seen in the majority of paths to receivers as well as direct path to the transmitter drag test. Twenty-three position solutions (Figure 18) were estimated, which is low; the positions estimates are not provided with an error rate.

Lotek does not report the detection efficiencies for the stationary transmitters.

*Due to reporting inadequacies by Lotek, this question cannot be fully addressed. To facilitate comparison with the HTI-Vemco results, the following has been requested from Lotek:

- For each site for each test a table that has:
  Node Location (as a row), Total Detections, Sync Detections, Reflections, False Detection Rate

- For each site for each test a table that has:
  Total Number of Calculated Positions, and Position Estimate Error Rate.

As evident in the HTI-Vemco USA data, Table 8, increasing from 3 to 4 receivers to position a fish, will decrease the position estimate error.

3) *Are the technology platforms susceptible to code collisions?*

HTI-Vemco USA: This question is addressed by altering the ping interval rate (PIR) to reduce transmitter code collisions. "Collisions are normally not a factor for Vemco HR2 receiver systems, unless hundreds of tags must be tracked simultaneously. In a case where 100 tagged fish are being monitored simultaneously the recommendation would be to limit transmission intervals, to 1.5-2 seconds for 100 tags and 3-4 seconds for 200 tags. Collisions would not be a problem for the planned study if tag transmission intervals were similar to the pilot study at 3 seconds per pulse." (Report page 24)

Lotek Wireless, Inc.: This question is addressed (Section 4.2) as "the JSATS coding architecture is designed with collision resistance as one of its primary properties, it is likely safe to attribute the observed low detection rates to something other than code collision." The technology (BSPK code is 31-bits in length, 744 microseconds in duration), frequency, code space (near 65k unique codes for a single frequency within a basin) and proposed number of transmitters is a good indicator of the collision resistance of the Lotek system.

*Both platforms are susceptible to code collisions at a very low rate. Collision rate is dependent upon signal type, number of transmitters in a defined area and the pulse emitting rate (PIR, ping rate, etc.), and time of arrival to the receiver. Because of the transmission signal/code difference and basic technology employed by both vendors, HTI-Vemco may be more susceptible to transmitter collisions than Lotek's system. Again, for either technology, the collision rate is expected to be very low. For the long-term study, code collision may only become a minor factor during mating when and if fish congregate in a small shallower water zone.

4) *What is the accuracy and precision of the positioning of tags?*

HTI-Vemco USA: "Table 7 shows the absolute position accuracy, or difference between the mean calculated stationary tag position and the measured GPS tag position. The absolute accuracy ranged from 6.91 to 36.31 m for all tags at both sites. Absolute position accuracy assumes that the GPS measured position for the stationary tags was accurate, but these positions may have had errors of up to 2-3 meters, since they were taken with a hand held Garmin GPS. In addition, no attempt was made to adjust the overall array location to match the measured tag positions. Adjustments in receiver positions made to fit the signal delays measured from receiver transmissions do not take into account absolute locations and can skew the absolute location of the array, even though the relative receiver positions are precise. The precision of the tag positions as measured by the three stationary tags in each array is summarized in Table 8. Precision (mean error values) ranged from 1.49 m to 9.84m for all positions, and 1.12 m to 3.69 m for positions calculated from 4 or more receivers. No filtering or position limitations were applied to the data." (Report page 24)

In the Cove, the stationary transmitter test position efficiency was 5.77, 74.21, and 83.34%. At the Port site, stationary transmitter test position efficiency decreased overall to 27.32, 49.54, and 58.62%. The variance of the positions (in terms of actual distance) fits with the position error efficiency estimates.

Lotek Wireless, Inc.: Lotek did not provide a direct response to this question. For the stationary transmitter test, Lotek reported (section 4.3) "the array configuration in the Cove resulted in only a small number of position estimates being generated and scatter in those points around the known tag mooring location is seen. This scatter is expected as although the design of the moored tag test specified that the three moored tag locations would be located so as to represent an ideal, sub-ideal and grossly sub-ideal location with respect to array geometry, the actual CL2-CL3-CL4 array resulted in all tag moorings being outside of the array footprint. In the case of the Port array, detection and positioning performance was considerably improved over that seen in the Cove. While a high number of position estimates was generated in UMAP, the observed scatter in the positions generated was quite pronounced in some cases, likely caused by properties of the Port acoustic environment."

Lotek provided position estimates for each test by location. The Cove transmitter drag test yielded 2 positions per transmitter (Figure 16). The Port transmitter drag test yielded 8 and 15 positions per transmitter (Figure 18). The Cove stationary transmitter test yielded 1498, 127 and 664 positions (Figure 21). The Port stationary transmitter test yielded 51960, 92227 and 44320 positions (Figure 23).

Lotek did not provide actual percent efficiency rather, they provided the detection events. However, using the position solutions and detection events provided in Lotek's draft report, the following position efficiencies are calculated:

- The Cove transmitter drag test yielded positions efficiencies of 100 and 50% per transmitter (Figure 16).
- The Port transmitter drag test yielding positions efficiencies of 66.7 and 88.2% per transmitter (Figure 17).
- The Cove transmitter stationary test yielded positions efficiencies of 46.9, 41.8 and 32.6% per transmitter (Figure 21).
- The Port transmitter stationary test yielded positions efficiencies of 97.8, 94.6 and 91.1% per transmitter (Figure 23).

*The quadrilateral design at each site and stationary transmitter placement were well developed and performed as intended, that is, to challenge the vendor's equipment and show strengths and weaknesses of the competing technology. The decrease in position efficiencies for either vendor technology should be expected in challenging acoustic environments due to signal attenuation, reflection and refractions of signals on hard surfaces (i.e., hard substrate, channel walls), and other anthropogenic noise sources (i.e., depth finders).

There is no doubt that the Lotek receiver malfunction in the Cove greatly reduced their ability to determine positions and report position efficiencies. As a result, HTI had much higher position efficiency in the Cove for stationary transmitter test. For the Port site, Lotek had higher position efficiency (per my calculations above) yet much lower number of positions reported than the reported position efficiencies yet higher number of positions by HTI for the stationary transmitter test. One could conclude that Lotek used a filter setting that reduced the number of positions reported to increase the position efficiency. For the long-term study, number of positions is just as important as position efficiency. Additional receivers can be placed in areas to increase efficiency, but lost data or inability to determine position (i.e., the ability to report number of positions) cannot be corrected as easily.

5) *If high-resolution 2-D positioning is not possible, what designs would permit lower resolution tracking at the site, for example, using "gates" or receiver transects to provide presence/absence information to isolate the presence of fish within segments of the river and river side?*

<u>HTI-Vemco USA</u>: "Based on the tag drag data (Figures 13-22, and 25 and 26) and on detection efficiency of stationary tags, 'gates' or line arrays of receivers across the Willamette would be feasible, and efficient to install. For optimum redundancy and certain detections of all passing tagged fish, spacing of receiver mounts at 200 to 300 m apart (two to three receivers at the locations

monitored) would be best. Additional receivers for very important gates might be considered for additional redundancy. The specific spacing and number of detection gates would depend on the relative allocation of receiver resources between fine-scale 'hot-spot' arrays and detection gates for defining the general zones tagged fish were located in." (Report page 24)

Lotek Wireless, Inc.: Lotek does not directly address this question. In the conclusion of the report (section 4.5), Lotek recommends a system of combined radio and acoustic monitoring. Specifically, they state that "through the use of a combined acoustic/ radio telemetry system. This system would offer flexibility with respect to station location and deliver zonal Coverage, on the order of 10's of meters. If finer scale positional information is required, an acoustic system could be combined with the radio system, to provide fine scale positional information in areas identified as benefitting from higher resolution habitat utilization by SMB or other tagged species."

*This question will ultimately be dependent upon the site selection, length x width x depth of site, and environmental conditions including flow and acoustic challenges.

6) *What receiver installation/mounting techniques will be effective?*

HTI-Vemco USA: "The mount design used for the pilot study performed well, although careful attention to placement and bathymetry would allow for the best detectability of all fish tags. Sand bars or other bathymetric features between the receivers and shore should be avoided to allow for complete river cross-section Coverage. A bathymetric map of the study area is essential to select locations that provide optimal receiver and tag positioning performance. Mount locations should be chosen that allow for direct line of sight of most areas of interest where tagged fish might reside. Robust, weighted bottom mounts will ensure stationary receiver deployments that are important for accurate tag positioning. No surface presence is important to discourage vandalism, and to protect from entanglement with large floating debris, or interference with boat traffic. Some locations may allow for a cabled receiver deployment to provide real-time detection data. All HR-2 receivers may be operated with a cable." (Report page 24)

HTI-Vemco states that (section 5) "A bathymetric map of the study area is essential to select locations that provide optimal receiver and tag positioning performance. Mount locations should be chosen that allow for direct line of sight of most areas of interest where tagged fish might reside. Robust, weighted bottom mounts will ensure stationary receiver deployments that are important for accurate tag positioning. No surface presence is important to discourage vandalism, and to protect from entanglement with large floating debris, or interference with boat traffic."

Lotek Wireless, Inc.: Lotek does not directly address this question. In Section 4, recommendations included "Proper protocol for the deployment of an acoustic positioning array calls for a number of steps to be executed in a specific order. The success of each step forward rests on the results of the previous step, until the final step of array deployment. The array dimensions employed in the Pilot Study were extreme for the JSATS system and not based on site-specific range test data. The observed inability of the system to deliver the high rate of detections and position estimates seen in other studies is disappointing, but not unexpected."

*This question will ultimately be dependent upon the site selection, length x width of the site, the bathometry and slope, sediment type, and environmental conditions including flow and other acoustic challenges. Lotek did put forth other considerations for effectiveness including developing a site-specific test before deployment.

7) *What are potential challenges associated with implementing a full-scale study?*

HTI-Vemco USA: HTI-Vemco states (Section 6) that "Array maintenance will be a key component of the study design, and transponding allows for regular array status assessment. During the 5-day pilot study, all receivers remained in place, and continued to operate correctly. Over longer time periods or during high flow events, receiver operation may be compromised by bed load movement and/or debris. Transponding allows for detection of these problems without receiver retrieval and data download."

Lotek Wireless, Inc.: Lotek does not directly address this question. However, throughout the report, challenges by Lotek were highlighted.

- Array dimensions should take into consideration the limitation of the 416 kHz transmitted signal that is 75-150m between autonomous nodes. Sec 4.2 states "Had there been an opportunity to conduct tests to optimize the configuration of the test tag deployment technique prior to completing the drift tag transects the results of these transects might have been improved."

- Sec 3.2/4.1: Based on acoustic work carried out in many Ports, the RM11E Port area is an acoustically challenging environment owing to the hard reflective surfaces presented by walls and the hulls of ships and barges. Additionally, the noise and air entrainment associated with the operation of propellers further degrades the acoustic environment. From a hydro-acoustic perspective, Ports typically represent a challenging environment, with high levels of anthropogenic noise and many highly reflective surfaces which encourage multi-path.

- Sec 4.5: A low frequency acoustic telemetry system (76 KHz) or combined acoustic/radio telemetry system would provide detection ranges 2-4 times that observed in the current JSATS (416 KHz) study (though with a tradeoff of expected transmitter operational life), thereby greatly reducing the number of hydrophones required to Cover the area of interest.

*Both vendors highlight important challenges that should be thoroughly examined before undertaking a full scale deployment. In order to better guide the selected vendors, acceptance criteria should be developed and explicitly stated for the experimental design. The criteria will depend upon the final design, yet be inclusive of expected number of positions, position efficiency, filter use and to what degree, present/absence data vs 2D vs 3D, etc. This will be important to ensure that the selected vendor and associated contractors understand the expectations of Exxon-AECOM. The criteria can be used later, if needed, for legal purposes to highlight and defend the project experimental design, expectations and results (so if possible have stakeholders review for buy-in).

8) *What level of effort is required to maintain and obtain data from a deployed array?*

HTI-Vemco USA: See Report page 25; HTI-Vemco provided a page long response but did not quantify effort. Recommendations are to maintain receivers every two months with mobile surveys every two weeks using the HR-2 transponder.

Lotek Wireless, Inc.: Lotek did not address this question.

9) *Recommended equipment and a proposed receiver array for conducting the year-long full-scale survey for capturing SMB movement on a fine-scale basis and/or on a presence/absence basis.*

   Neither vendor addressed this question by providing quantification of effort and costs.

   * To receive a well-developed, quantified effort and fiscal estimate from the vendor, it is recommended that the project sponsor provide a detailed scope of work that identifies river reach and site selection detailed by presence/absence or 2D (or 3D) fine-scale positioning needs; time of year Coverage; number of fish; tagging effort and so on.

Conclusions:

The development of fish telemetry techniques has greatly expanded collection of basic biological data. In selecting the type of telemetry system, the appropriate tool depends on the species, life history stage, habitat (e.g., benthic, pelagic, resident or migratory), resolution required, sample size, size of the study area, time over which data is required, personnel availability and experience, and budget. Although no method is 100% effective, each telemetry technology has specific capabilities and limitations as demonstrated by the vendors in this pilot study.

The proposed study area, 10 miles of the Lower Willamette River, has inherent challenges given the bathymetry, water flow and velocities, urban setting, vessel traffic of all sizes, anthropogenic noise, channelization, remediation sites, and predators from fishermen to marine mammals. The system developed should be durable and robust to environmental and human interferences. Both vendors during deployment and in their reports have shown that they understand the difficulties of the region.

The HTI-Vemco USA system overall out-performed the Lotek system based on the data analyses of the transmitter drag tests, stationary tests, and the receiver performance. This conclusion is based on the overall detection range and efficiency results for both sites, as well as the position efficiency and accuracy results provided in the vendor's reports.

For the long-term acceptance and therefore project success, it is recommended that acceptance criteria are developed and explicitly stated for the experimental design. This will be important to ensure that the selected vendor and associated contractors understand the client expectations and acceptance criteria for the study data. This can also can be used later, if necessary, for legal purposes to highlight and defend the project experimental design, expectations and results.

As previously stated, this memo has been developed based on Lotek's draft report and the information presented in their August 15 webinar. I can revisit my summary and update comments and recommendations based on the final report, if needed. Until then, please let me know if you have questions on the above material.

Christa M. Woodley, PhD

ATTACHMENT C

SUMMARY OF CAMERA PILOT STUDY

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Memorandum

To	Deborah Edwards/ExxonMobil	Page	1
CC	Ryan McCarthy		
Subject	Summary of Portland Harbor Superfund Site Camera Pilot Study		
From	Betsy Ruffle and Mandi McElroy		
Date	September 12, 2017		

This memorandum summarizes the objective, methods, and results of a pilot camera study at the Portland Harbor Superfund Site, and provides recommendations for utilizing cameras to meet future project objectives.

Objective

A camera study was included in the fish tracking pilot study performed during June 13 to June 19, 2017 at the Lower Willamette River in Portland, Oregon. The objective of the camera study was to field test the suitability and effectiveness of wildlife cameras for monitoring activity at the river in the vicinity of the two offshore areas where fish tracking equipment was deployed (Willamette Cove at River Mile [RM] 6.8 and RM 11.5 East). The results of this initial camera study may be used to inform the potential future use of cameras to document and assess angler activity in the Lower Willamette River study area for the Portland Harbor Superfund Site.

Methods

A total of four wildlife cameras were deployed at the two fish tracking pilot study locations (two cameras at each location: Willamette Cove near RM 6.8, and RM 11.5E). Prior to the site visit, aerial imagery was used to identify potentially-suitable camera locations.

Each camera was programmed for motion activation and tested prior to deployment, and fitted with a 32 GB memory card and eight AA lithium batteries. The camera model used was the ZenNutt HD Wildlife Trail & Game Camera. Features of this camera include:

- Waterproof
- Infrared Night Vision
- Motion-Activated
- Time-Lapse
- 2.4” LCD screen
- 0.2-1s second trigger speed
- 12 megapixel 1080P high quality still images, day and night
- 120°detection angle and a 65-foot detection range

On June 12, 2017, three camera locations were accessed by boat. On June 13, 2017, the fourth camera site was accessed on land, at the Cargill property, with permission of the facility manager. All cameras were visited one day post-installation for a maintenance check, and photos were reviewed to adjust the camera position and settings as needed.

The final settings used on all four cameras for the duration of the study were:

- Mode = Photo
- Resolution = 8 megapixels
- Video = Off
- Audio = Off
- Shot Lag = 10 minutes
- Side Motion Sensor = Off
- Photo Series = 1
- Sensitivity = Medium (reduced from “Low” on Day 2)
- Shot Lag = 10 minutes
- Time and Date Stamp = On

Each camera was directed at an area where fish tracking equipment was installed (see **Figures 1** and **2**). The use of two cameras at each pilot study location provided two fields of view and captured the hydrophone array, which covered an area of approximately 400 x 400 feet at RM 11.5E and 300 x 600 feet at Willamette Cove. To the extent possible, each camera was hidden from view or in an area difficult to access, in order to reduce the possibility of theft or tampering. Cameras were removed on June 19. Photographs were uploaded and reviewed on July 17, 2017 and stored in a project database. Table 1 provides a summary of each camera location and dates of deployment, adjustment, and removal.

Table 1. Camera Locations and Dates of Deployment, Maintenance, and Removal Dates.

Camera Number	SD Card	Location Coordinates	Site	Descriptive Location	Deployment Date/Time	Camera Check/Settings Adjustment	Removal Date/Time
1	A	45.53468°N 122.6746°W	RM 11.5	On a tree trunk inside chain-link fence at Cargill, facing south.	6/13/2017, 0915	6/14/2017, 0912	6/19/2017, 1557
2	B	45.53325°N 122.67336°W	RM 11.5	On a dead tree trunk in the water, facing west.	6/12/2017, 1534	6/13/2017, 1606	6/19/2017, 1110
3	C	45.57920°N 122.74511°W	RM 6.8	On a tree trunk on shore, facing north.	6/12/2017, 1452	6/13/2017, 1634	6/19/2017, 0743
4	D	45.58076°N, 122.74823°W	RM 6.8	On a piling in the water, facing southeast.	6/12/2017, 1350	6/13/2017, 1648	6/19/2017, 0656

Results and Discussion

The two camera locations at each site provided a clear view of the area where fish tracking equipment was deployed. Photo clarity and resolution at the 8 megapixel setting was very good and provided clear image definition, color and contrast at distances of up to several hundred feet. Attachment A provides photos of the camera locations, and a representative photo of each camera's field of view. Table 2 provides a summary of the number of photos captured by each camera.

Table 2. Photo Count per Camera.

Camera	Total # Photos	Number of Photos per Day							
		12-Jun	13-Jun	14-Jun	15-Jun	16-Jun	17-Jun	18-Jun	19-Jun
1	52	0	12	10	3	6	7	6	8
2	32	0	11	4	1	2	4	8	2
3	674*	470	167	14	0	0	11	11	1
4	33	0	2	12	0	0	8	11	0

* The large number of photos captured by Camera 3 on the first and second days were caused by a branch moving in front of the camera, which was removed on Day 2 of the study.

The majority of the activity captured by each camera was boat and barge movement. Boats in transit were most commonly observed. Generally, the view of the study area at RM 11.5E was somewhat restricted by the changing position of the barges at Cargill and the limited surfaces available in the area for camera attachment. The opposite side of the river was assessed on Day 1, but was determined to be at too great a distance to monitor activity at the study site. Activity at Camera 1 was highest on June 13 and 14 when multiple barges entered and exited the Cargill docks throughout the day. Camera 1 captured one night photo of a vessel moving through the area. The field of view of Camera 2 was partially obscured by vegetation, and most frequently captured tugboats moving in and out of Cargill's port.

At the Willamette Cove location, activity increased on the weekend (June 17-18), due to increased transit of private boats in the cove. Several private boats were anchored in the cove at RM 6.8 and occasionally left and returned, or changed position. A tree branch in front of Camera 3 caused the camera to deploy over 600 times in the first 24 hours; during the maintenance check on Day 2, the branch was removed and the sensitivity setting was changed from "Low" to "Medium", which resolved the issue. The field of view from Camera 3 included private boats moored in the cove. Photos of people viewing Camera 3 were captured twice, at different times on June 13 after the maintenance check (Figure 3). None of the cameras were tampered with.

Figure 3. Spectators observing Camera 3 from the water in Willamette Cove.

Besides the June 13 photo of the individual possibly line fishing (Figure 3, right photo) and another possible line angler in Willamette Cove on June 18, no photos of anglers or fishing activity were captured during the week-long study period.

Recommendations for Future Study

The camera pilot study demonstrated the suitability of the tested field cameras for capturing clear images in the two study plots. For a future camera study in the Portland Harbor Study Area, the following recommendations are provided:

- For large study plots similar in size to those used for the fish tracking equipment (a few acres), two cameras positioned at opposing angles should capture a sufficient view of the area of interest. Larger areas may require additional cameras for a comprehensive view. One camera is expected to be sufficient at smaller areas, such as boat docks and ramps.
- For study plots with an obscured view at ground level, such as the barges and vegetation at RM 11.5E, the camera should be placed at a substantial height and angled down toward the study plot in order to fully capture the area that would otherwise be a “blind spot”.
- If cameras are placed in areas accessible to the public, cameras should be camouflaged to the extent possible, and ideally placed in locations that are difficult to access. “Property Of” labels can also be attached to the cameras to deter tampering.
- Identification of camera installation locations on private property with a clear view of the study plot may be an alternative to public settings. A reconnaissance of the river may help to identify candidate locations for installing cameras at identified fishing spots.
- Although the motion detection setting is sufficient to capture movement within the field of view, the results are limited to activity, and periods of inactivity are assumed for time periods during which no photos are taken. In order to routinely quantify both activity and inactivity during the full study, the cameras could be programmed to deploy at regular intervals (e.g., capture one photograph every 15-30 minutes during daylight hours). In order to ensure that all activity is captured, the interval time length should be equal to or less than the average

amount of time it would take for an activity to end and begin within the field of view. For example, if a boat ramp is typically occupied for about 20 minutes by an angler, a time interval of 15 minutes may be appropriate.

- Cameras should be checked within 24 hours of installation to evaluate in-field performance, including operation as programmed (e.g., image capture frequency), sensitivity of settings, the presence of branches or other objects that may obscure view, and overall image quality.
- Installed cameras should be checked regularly for maintenance (battery and memory card change-out) and performance monitoring. During the first month of use, cameras should be checked twice to ensure they have not been tampered with and to monitor battery life and memory card usage. Battery and memory card change-out should be performed monthly thereafter.

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Notes:

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Figure 1
Vessel Routes and Actual Hydrophone and Camera Locations at RM11.5E Study Area
Lower Willamette River Fish Tracking Pilot Study
Portland Harbor Superfund Site

J:\DCS\Projects\ENV\PROJECTS\EXXONMOBIL\1_Sustainabilty (60441493)\900- CAD GIS\GIS\MXDs\New Sample Figures\Figure 2 Camera Willamette Cove.mxd

Notes:

Figure 2
Actual Hydrophone and Camera Locations at Willamette Cove Study Area
Lower Willamette River Fish Tracking Pilot Study
Portland Harbor Superfund Site

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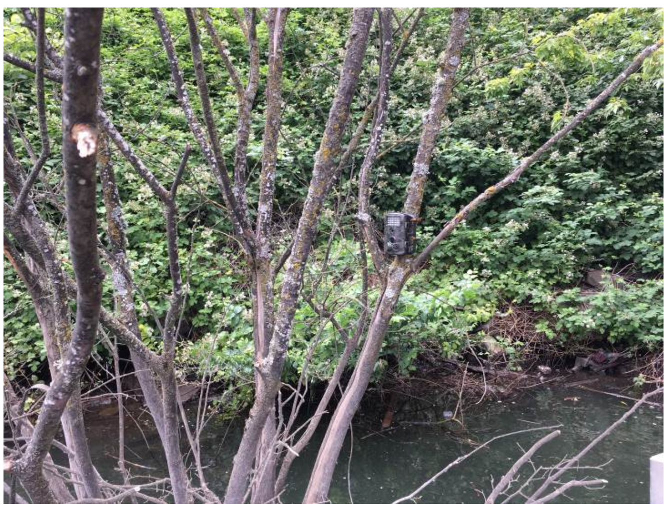
ATTACHMENT A - REPRESENTATIVE PHOTOS

Camera 1 placement.

Camera 1 field of view.



Camera 2 placement.

Camera 2 field of view.

Placement and Field of View for Cameras 1 and 2 at RM11E

September 12, 2017

ATTACHMENT A - REPRESENTATIVE PHOTOS

Camera 3 placement.

Camera 3 field of view.

Camera 4 placement.

Camera 4 field of view.

Placement and Field of View for Cameras 3 and 4 at Willamette Cove

September 12, 2017